K A P I T E L   VII

IN VITRO UNTERSUCHUNGEN ZUR ERMITTLUNG DER VERDAULICHKEIT, DES GEHALTES AN UMSETZBARER ENERGIE UND DER PROTEINVERFUGBARKEIT BEI TROPISCHEN FUTTERBAUMEN UND BUSCHEN

CHAPTER VII

IN VITRO STUDIES FOR THE PREDICTION OF DIGESTIBILITY, METABOLISABLE ENERGY CONTENT AND PROTEIN FERMENTABILITY OF SHRUB AND TREE FODDERS

C H A P I T R E   VII

MESURES *IN VITRO* DE LA DIGESTIBILITE POUR ESTIMER LES TENEURS EN ENERGIE METABOLISABLE ET EN AZOTE DEGRADABLE DANS LE RUMEN DES FOURRAGES LIGNEUX

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List of abbreviations

T, DM	Dry matter
XA	Crude ash
OS	Organic matter
XP	Crude protein
XL	Crude lipids
XF	Crude fiber
XX	N-free extractives
NDF	Neutral detergent fiber
ADF	Acid detergent fiber
ADL	Acid detergent lignin
Hemic	Hemicellulose
Cell	Cellulose
Gb	Gas production (ml/200 mg DM in 24 h)
dOS	organic matter digestibility
ME	Metabolizable energy
PAB	Protein availability; protein degradability in rumen liquor in vitro
SMS	Pepsin-cellulase-solubility of dry matter
SMO	Pepsin-Cellulase-solubility of organic matter
NPro	Protein solubility in pronase
NADF	ADF-bound nitrogen
ADFIN	Acid-detergent-soluble N (XP - NADF)
TanP	BSA-precipitable tannins (Grillet and Villeneuve 1994)
NIRS	Near-infrared-reflectance-spectroscopy
n	number of investigations
MW	Mean
SD	Standard deviation
RSD	Residual standard deviation (as % of mean)
Min	Minimum
Max	Maximum
r	Coefficient of correlation
r^2	Coefficient of determination

1. Introduction

Nutrition of ruminants in West Africa is mainly based on crop residues and natural pastures which are of low quality especially in the dry season. Besides its low protein content and low protein availability frequently the low energy content is limiting production, hence allowing only poor levels of performance. To increase productivity of animals, supplementation is necessary, but the use of suitable industrial byproducts or concentrates is limited due to its availability and costs, however. On the other hand, a lot of different browse species are growing at these sites of which leaves, branches and fruits can be utilized as feeds and which play an important role as supplements, as they maintain a more favourable nutrient quality during the dry season.

The knowledge of the nutritive value of these browse species is still limited and not systematically investigated (DIAGAYETE 1981; RITTNER 1992). Therefore, the aim of this project was to assess a systematical and comprehensive review of the nutritive value of browse species. For this purpose, it is not sufficient however, to analyze only crude nutrient and mineral contents, also the consideration of secondary plant ingredients is necessary. Most important seems to be the estimation of digestibility and energy content, as energy is in most cases the first limiting factor that restricts productivity.

For the determination of digestibility normally the standardized digestion trial using small ruminants is applied as the reference method. But especially under conditions in the tropics it is often difficult or even impossible for several reasons to carry out digestibility trials with animals. In addition, this method is not suitable to test large numbers of feedstuffs as it was necessary in the present study. As an alternative, in vitro methods to predict digestibility and energy content can be used. With these methods it is possible to analyze large numbers of samples spending only moderate amounts of cost and time and, what is essential, with a sufficient accuracy of prediction allowing to gather a comprehensive review of the energetic feed value. In addition, these in vitro methods can be used for the calibration of even more simplified indirect methods, as for example the technique of near-infrared-reflectance spectroscopy.

In the present study the gas production method (MENKE et al. 1979) was applied. In comprehensive investigations (MENKE and STEINGASS 1988) the capacity and accuracy for prediction of the energetic feed value could be demonstrated for this method. Using a modification of this technique (LEINMÜLLER 1989) it was also possible to estimate the availability of nitrogen in the rumen, an information which is of particular importance in browse as these feeds frequently contain secondary substances, for example tannins.

2. Materials and methods

2.1. Gas production method

The principle of this method is that the amount of gas which is released during the incubation of feedstuffs with rumen liquor in vitro is closely related to digestibility and hence energetic feed value of feedstuffs for ruminants. The gas (CO_2 and CH_4) originates mainly from the degradation of carbohydrates. Therefore, gas production is primarily a measure of digestibility of carbohydrates. On the contrary, lipids have a high energy content, whereas their contribution to total gas production is only small. A similar situation is found for crude protein: indeed, comparable amounts of gas are produced from degradation of amino acids as from carbohydrates, but this CO_2 does not quantitatively appear in the gas phase, as NH_4HCO_3 is formed from CO_2 and NH_3 which is simultaneously released from protein degradation so that the prevailing amount of CO_2 is not measured. The consequence is that for a most accurate prediction of digestibility the contents of crude protein and crude fat of the feeds under test have to be used in addition to gas production. Therefore, the equations for the prediction of digestibility and ME (see below) contain crude protein and crude fat besides gas volume as independent variables.

The gas production method was carried out according to MENKE and STEINGASS (1988) with the exception that for each sample 2 parallel measurements were taken at 2 different days so that the mean was calculated from 4 single observations. At the same time where gas production was measured, dry matter content of the samples (4 h at 376^{o} K) was determined in order to correct gas production exactly to 200 mg DM.

The incubation with rumen liquor was carried out in a ventilated oven at 312^{o} K for 24 hours. As donor animals for rumen liquor 2 lactating Holstein cows with permanent rumen cannula were used. The cows were fed according to milk yield with a ration consisting of 70 % grass hay and 30 % concentrates. Rumen liquor was taken before morning feeding and mixed from both cows.

From total gas production of the samples blank values (gas production from inoculum without feed) was first subtracted followed by a factor correction using standard feedstuffs (hay and concentrate with defined gas production). For the calculation of OM-digestibility and ME-content the following equations were used (MENKE and STEINGASS 1988):

digestibility of organic matter (dOS; %)

$$dOS = 14.88 + 0.8893\ Gb + 0.448\ XP + 0.651\ XA$$

metabolizable energy (ME; MJ/kg T)

$$ME = 1.68 + 0.1418\ Gb + 0.073\ XP + 0.217\ XL - 0.028\ XA$$

XA, XP, XL	as % of T
Gb	as ml/200 mg T in 24 h

These equations were derived from 400 feedstuffs with known in vivo digestibility. These feeds were of very heterogenous composition. dOS ranged between 29.7 and 94.8 %, the

ESTIMATION DE LA DIGESTIBILITE DE LA MATIERE ORGANIQUE A PARTIR DE LA PRODUCTION DE GAZ

Echantillon séché broyé

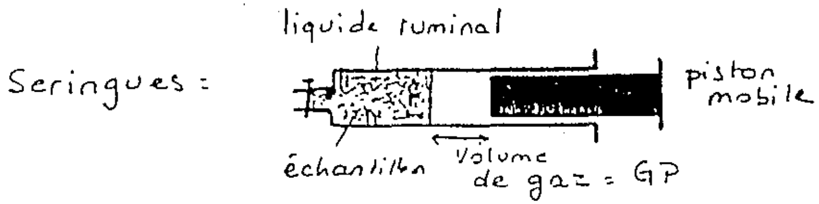
Animaux donneurs : 2 Bovins
ration standardisée
prélèvement du jus de rumen

jus de rumen + solutions (1/2V)

Seringues :

- 4* "Blancs" : 30 ml sol. (GP_0)
- 4* Contrôles :
  200mg luzerne standard (GP1)
  200mg concentré standard (GPc)
- 2* échantillons à tester : 30ml sol. + 200mg éch.

Incubation : Rolleur 39°C 24h
lecture V_0 V_8 V_{24}



L'échantillon est incubé avec du jus de rumen dans un tube calibré fermé par un piston mobile à 39°C pendant 24 h. Le volume de gaz produit est corrigé par la production de gaz dans un tube témoin et par celle d'un aliment standard. Faute de données relatives aux fourrages ligneux tropicaux, l'équation de prévision de la DMO à partir de la production de gaz utilisée est une équation générale (page 2)

Calcul de la GP

$$GP(ml/200mgMS) = \frac{(V24-V0-GP0)*200*((GP1+GPc)/2)}{\text{pd prise d'essai en mg MS}}$$

Estimation de la DMOGT

$$\boxed{DMOGT = 15{,}38 + 0{,}8453GP + 0{,}0595MAT + 0{,}0675MM}$$

DMOGT en %MO

MAT MM en g/kgMS

(Brigitte ARBELOT 1993)

contents of ME varied between 4.1 and 15.3 MJ/kg T, hence covering the expected range of the samples in the present study. The coefficient of determination (r^2) of these equations is 92 and 95 % and the residual standard deviation ($s_{y.x}$%) is 4.2 and 4.1 % for the estimation of dOS and ME respectively.

In Hohenheim only the gas production of the samples was determined. The crude nutrient composition which is necessary for the calculation of dOS and ME was analysed by other participants of the project. In the present study, gas production was determined in 1123 samples.

2.2. Estimation of protein availability (PAB)

As in the samples under test not only crude protein content is an essential criterium for nutritive value, but as especially in these feedstuffs the presence of tannins and other secondary compounds which may adversely affect protein availability is of special importance, the determination of protein degradability in vitro gains significance. Therefore, in 221 samples, protein degradability in vitro was estimated.

As in vitro method for this purpose a technique developped by LEINMÜLLER (1989) was used. This method is based on investigations of THOMSEN (1985), who determined protein degradability by measuring dry matter digestibility according to TILLEY and TERRY (1963) using a N-deficient in vitro system where carbohydrates are in surplus. The principle of this method is, that dry matter digestibility is linear related to N-availability as long as N is deficient. LEINMÜLLER (1989) has modified this method using gas production in vitro instead of dry matter digestibility as a measure for fermentative activity and hence for N availability. One problem is the choice of a suitable reference-N-source. While THOMSEN has used a urea-amino acid mixture as 100% available N-source, LEINMÜLLER took NH_4HCO_3. The calculation of N-availability of the samples to be tested is done by comparing the gas production of the sample with gas production measured with the reference N-source at the same N-levels:

$$\text{N-availability; PAB (\% of N)} \quad \frac{\text{gas production at 2 mg N (sample)}}{\text{gas production at 2 mg } NH_4HCO_3} * 100$$

To ensure a N-deficiency of the inoculum only 1 ml of rumen liquor was used and the NH_4HCO_3 which is normally added to the buffer was left out. To guarantee a sufficient surplus of carbohydrates 400 mg pure starch was added to each incubation syringe. The samples were incubated in triplicates, the reference N-source was incubated in 5 parallels.

The problem in the estimation of N-degradability is primarily due to a lack of standard samples with known in vivo N-degradability. In a comparison of this is vitro method with N-degradability using nylon-bags on 25 roughage samples, the same ranking of degradability was found in both methods, however (ROTHFUSS 1991). Therefore, the results obtained by this method can be used as a relative measure of N-availability. It is not justified, however, to use these results as absolute values, because it is not possible to define a standardized protein degradability as we are used to do with organic matter digestibility for example.

ESTIMATION DE LA DEGRADABILITE DE L'AZOTE A PARTIR DE LA PRODUCTION DE GAZ

<u>Solutions</u> :
idem DMOGT + Jus de rumen (1/29V)

<u>Seringues</u> :

-3* "blancs" :
400mg d'amidon + solution ruminale

- Témoins (*3) :
  - 0,5mg N
  - 1mg N
  - 1,5mg N
  - 2mg N
  - 2,5mg N

  + 400mg amidon

N= (NH4)HCO3

-2* échantillons à tester :
30ml solution + échantillon (prise d'essai correspondant à 3mg d'azote) + 400mg d'amidon.

<u>Incubation</u> :

Rolleur 48h à 39°C

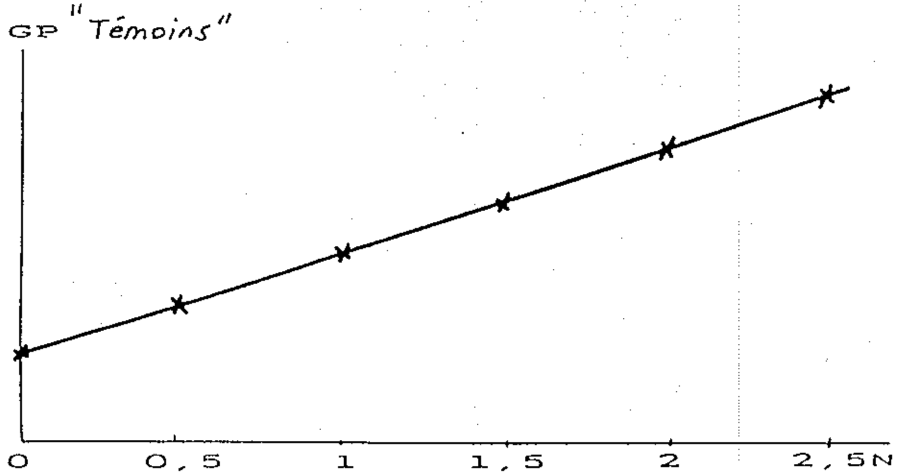
Lecture : 12h, 24h, 32h, 48h.

L'échantillon est incubé dans du jus de rumen en présence d'un excès de sucres fermentescibles (amidon). La production de gaz est donc considérée comme proportionnelle à la quantité d'azote fermentescible. La teneur en azote fermentescible de l'échantillon testé est calculée par une régression linéaire établie à partir de tubes témoins contenant la même quantité d'amidon et des quantités croissantes d'une source azotée fermentescible ($(NH_4)HCO_3$)

<u>Calcul de la dMAGT</u>

Témoins --> <u>GP (ml/48h)=a+bN(mg)</u>

==> dMAGT en %MAT



(Brigitte ARBELOT 1993)

3. Results and discussion

Review over the total sample pool

In table 1 a review of the in vitro results for the whole sample pool is given. The statistical values here and in the following tables were calculated using only these samples where gas production has been determined. Therefore, deviations in the statistical parameters from the results of other project groups are possible.

As mentioned already, in Hohenheim only gas production (Gb) and protein availability (PAB) were determined. OM-digestibility (dOS) and contents of metabolizable energy (ME) were calculated using gas production (Gb), crude protein (XP), crude ash (XA) or crude lipid (XL) contents respectively. Therefore, the values for these nutrients are shown in the following tables in addition to the in vitro parameters. The dimensions are as follows:

Gb	ml/200 mg dry matter in 24 h
dOS	%
ME	kcal/ kg dry matter
PAB	% of crude protein
XP; XA; XL	% in dry matter

Table 1: Parameters of nutritive value of the whole sample pool

sample		Gb	dOS	ME	PAB	XP	XA	XL
all	n	1123	1051	922	221	1055	1051	922
	MW	**24,0**	**49,5**	**1621**	**16,6**	**14,2**	**10,2**	**4,0**
	SD	11,3	12,3	424	16,8	5,6	6,5	2,5
	Min	0,5	16,0	541	0	0,4	0,7	0,3
	Max	77,2	87,3	3128	87,7	40,1	45,1	19,3

It is apparent, that there is a very large variation in all paramters which covers nearly the whole possible range of nutrient composition of roughages. This is not surprising, however, as here the means are taken over all species and plant organs tested. Therefore, the information from these data is very limited.

3.2. Results of in vitro investigations of single species

Table 2 shows the corresponding results of various single species. Only species and plant organs, respectively, were selected from which a sufficient number of observations (≥ 10) were existing.

Table 2: Parameters of nutrivive value of selected species

sample		Gb	dOS	ME	PAB	XP	XA	XL
Maerua	n	9	9	9	0	9	9	9
crassifolia	**MW**	**40,0**	**73,4**	**2383**		**23,7**	**18,8**	**6,4**
leaves	SD	2,4	1,3	153		2,9	3,7	1,2
	Min	35,1	71,5	2052		20,7	14,5	5,0
	Max	42,6	75,2	2545		28,4	25,9	8,3
Capparis	n	19	19	19	3	20	20	20
decidua	**MW**	**22,1**	**46,7**	**1442**	**25,7**	**15,6**	**8,4**	**1,6**
leaves	SD	5,9	6,9	261	5,4	4,3	1,1	0,4
	Min	15,7	40,4	1224	20,4	9,9	6,4	1,1
	Max	37,1	64,6	2097	31,1	25,1	10,7	2,3
Boscia	n	41	39	34	4	39	39	34
senegalensis	**MW**	**25,4**	**54,2**	**1666**	**23,8**	**22,5**	**10,1**	**2,3**
leaves	SD	4,3	4,2	101	7,9	4,8	2,4	0,6
	Min	13,5	46,9	1378	14,0	16,7	6,2	1,2
	Max	40,9	70,2	1914	32,0	35,1	16,5	3,4
Combretum	n	21	19	12	5	19	19	12
glutinosum	**MW**	**11,2**	**34,7**	**1515**	**3,5**	**11,2**	**6,7**	**9,9**
leaves	SD	5,3	5,0	195	1,8	2,7	1,4	5,0
	Min	3,6	27,5	1181	1,2	6,1	4,6	0,8
	Max	23,2	44,1	1754	5,3	17,4	10,5	16,4
Combretum	n	10	8	7	4	8	8	7
nigricans	**MW**	**10,9**	**34,4**	**1295**	**0,2**	**10,9**	**5,8**	**6,1**
leaves	SD	4,9	4,0	215	0,4	2,5	1,8	3,4
	Min	5,3	29,7	985	0	8,5	4,3	1,8
	Max	19,8	40,6	1628	0,8	14,8	8,9	11,1
Guiera	n	23	20	9	4	20	20	9
senegalensis	**MW**	**12,4**	**35,8**	**1252**	**1,2**	**12,1**	**6,4**	**5,2**
leaves	SD	4,4	5,4	126	2,2	3,2	2,2	1,7
	Min	6,7	29,2	1135	0	9,3	1,1	2,6
	Max	23,1	48,1	1490	4,4	20,2	10,6	8,2
Grewia	n	11	10	5	0	10	10	5
bicolor	**MW**	**22,1**	**50,0**	**1664**		**15,7**	**10,8**	**5,3**
leaves	SD	8,2	5,6	241		5,3	1,8	2,0
	Min	5,8	43,2	1381		4,2	8,1	2,3
	Max	31,8	58,0	1938		25,1	13,2	7,0

sample		Gb	dOS	ME	PAB	XP	XA	XL
Balanites	n	43	39	31	4	40	39	31
aegyptiaca	**MW**	**30,8**	**59,8**	**1862**	**32,6**	**15,1**	**15,9**	**4,4**
leaves	SD	5,2	4,2	133	13,4	4,7	2,5	1,5
	Min	16,8	49,8	1630	20,5	8,8	11,3	2,0
	Max	40,6	72,1	2073	49,7	32,4	22,8	7,7
Bridelia	n	11	10	10	0	10	10	10
ferruginea	**MW**	**13,0**	**35,2**	**1216**		**10,3**	**6,9**	**4,9**
leaves	SD	3,8	3,6	124		1,0	0,7	1,5
	Min	7,8	31,3	1021		8,5	5,6	3,5
	Max	17,4	40,5	1415		11,9	8,2	8,7
Hymenocardia	n	10	10	9	1	10	10	9
acida	**MW**	**18,9**	**39,2**	**1523**	**18**	**9,7**	**4,9**	**6,2**
leaves	SD	8,0	7,7	300		2,6	0,8	1,3
	Min	4,8	25,0	1052		7,0	3,5	4,2
	Max	31,3	50,3	1944		14,3	6,0	7,7
Margaritaria	n	9	9	9	0	9	9	9
discoidea	**MW**	**34,7**	**56,9**	**2011**		**14,4**	**7,2**	**4,4**
leaves	SD	5,1	5,0	215		1,5	0,5	1,3
	Min	21,9	44,5	1512		12,2	6,0	1,4
	Max	39,3	61,3	2196		16,6	7,9	6,5
Parinari	n	14	14	14	1	14	14	14
curatellifolia	**MW**	**8,6**	**32,6**	**879**	**3,6**	**8,5**	**9,6**	**1,9**
leaves	SD	1,6	1,8	77,5		0,8	2,5	0,6
	Min	6,0	29,9	700		6,7	6,3	0,5
	Max	10,8	36,4	987		9,5	15,4	3,3
Bauhinia	n	10	10	8	2	10	10	8
rufescens	**MW**	**19,4**	**46,1**	**1471**	**1,6**	**14,9**	**11,1**	**3,7**
leaves	SD	2,9	3,0	178		2,3	2,6	3,0
	Min	15,4	40,7	1235	0	11,3	7,8	2,0
	Max	24,5	51,6	1783	3,1	17,6	16,4	11,0
Bauhinia	n	9	9	6	2	9	9	6
rufescens	**MW**	**16,3**	**37,5**	**1234**	**6,4**	**11,9**	**4,3**	**2,1**
fruits	SD	2,9	3,1	68		1,9	0,4	0,3
	Min	12,5	32,2	1150	4,9	8,1	3,7	1,6
	Max	21,4	43,5	1348	7,9	14,9	4,8	2,5

sample		Gb	dOS	ME	PAB	XP	XA	XL
Piliostigma	n	9	7	6	1	7	7	6
reticulatum	**MW**	**18,3**	**40,7**	**1421**	**12,8**	**10,8**	**6,4**	**3,6**
leaves	SD	5,6	5,2	210		1,4	1,7	1,9
	Min	10,2	34,0	1149		8,7	4,1	1,8
	Max	28,6	48,3	1627		13,3	9,0	6,2
Piliostigma	n	25	23	19	3	23	23	19
thonningii	**MW**	**18,8**	**41,5**	**1499**	**7,0**	**10,6**	**7,0**	**5,7**
leaves	SD	6,0	4,9	192	0,6	2,5	1,6	2,2
	Min	7,6	33,9	1164	6,5	6,1	4,3	2,7
	Max	33,6	52,1	1888	7,7	16,9	9,8	9,7
Afzelia	n	10	10	10	1	10	10	10
africana	**MW**	**25,5**	**50,9**	**1944**	**26**	**17,2**	**8,6**	**8,4**
leaves	SD	4,0	3,6	174		3,4	1,8	2,7
	Min	16,1	42,8	1692		10,4	6,1	4,6
	Max	29,8	55,6	2185		22,0	11,8	12,6
Daniellia	n	28	25	23	9	25	25	23
oliveri	**MW**	**16,4**	**41,6**	**1286**	**7,7**	**11,6**	**9,9**	**3,4**
leaves	SD	6,7	6,3	341	6,1	3,6	3,3	1,0
	Min	7,0	33,1	872	0	6,5	4,9	2,2
	Max	37,8	62,9	2356	19,9	23,0	16,3	6,0
Gleditschia	n	26	26	26	1	26	26	26
triacanthos	**MW**	**42,5**	**60,7**	**2135**	**15,7**	**11,5**	**4,4**	**2,3**
fruits	SD	7,6	7,5	301		3,3	0,5	0,4
	Min	33,9	51,3	1731		5,9	3,2	1,6
	Max	63,2	82,1	2997		20,1	4,9	3,2
Parkia	n	13	12	8	0	12	12	8
biglobosa	**MW**	**9,9**	**32,9**	**1111**		**11,7**	**5,7**	**4,2**
leaves	SD	2,6	2,4	52		1,5	1,1	1,3
	Min	5,7	28,2	1046		8,9	4,5	2,7
	Max	13,4	37,3	1198		13,3	8,0	6,2
Leucaena	n	19	19	18	4	19	19	18
leucocephala	**MW**	**28,5**	**55,7**	**1920**	**14,0**	**22,0**	**8,5**	**4,2**
leaves	SD	4,6	4,8	205	8,7	4,7	2,9	1,5
	Min	21,7	47,4	1539	3,9	16,9	5,1	2,2
	Max	37,9	64,3	2239	23,8	31,2	18,3	8,5

sample		Gb	dOS	ME	PAB	XP	XA	XL
Acacia	n	12	12	11	4	12	12	11
senegal	**MW**	**24,3**	**57,9**	**1723**	**13,3**	**24,6**	**15,9**	**3,8**
leaves	SD	6,3	6,7	231	12,3	5,9	6,8	1,4
	Min	11,8	45,2	1380	5,6	18,2	8,5	2,2
	Max	34,5	65,5	2077	31,6	34,6	31,5	6,7
Acacia	n	15	15	14	7	15	15	14
nilotica	**MW**	**27,7**	**52,3**	**2005**	**28,4**	**14,0**	**10,0**	**9,5**
leaves	SD	5,3	5,8	341	17,8	1,5	3,3	4,3
	Min	13,1	36,1	1341	8,9	11,8	5,2	3,7
	Max	32,3	57,2	2593	54,9	17,4	17,0	19,3
Acacia	n	12	12	12	8	12	12	12
tortilis	**MW**	**22,5**	**50,4**	**1579**	**7,4**	**16,2**	**12,7**	**4,2**
leaves	SD	2,7	3,5	161	7,1	3,8	4,3	1,6
	Min	19,4	41,4	1261	0,8	8,6	8,4	2,1
	Max	27,8	55,1	1792	22,5	21,0	21,4	7,3
Acacia	n	12	12	12	1	12	12	12
tortilis	**MW**	**43,0**	**65,7**	**2231**	**4,6**	**17,7**	**7,1**	**2,1**
fruits	SD	3,9	3,4	154		2,3	1,8	0,5
	Min	36,7	59,7	1988		15,0	5,1	1,4
	Max	48,2	71,6	2456		21,5	11,0	2,9
Acacia	n	8	8	8	2	8	8	8
seyal	**MW**	**28,7**	**54,4**	**1818**	**35,4**	**16,8**	**9,9**	**4,2**
leaves	SD	7,0	3,7	219		5,3	4,0	0,9
	Min	14,4	47,4	1537	11,1	11,5	6,5	2,9
	Max	34,6	58,4	2061	59,7	28,1	18,5	5,7
Faidherbia	n	12	12	12	7	12	12	12
albida	**MW**	**22,7**	**47,8**	**1573**	**7,0**	**14,4**	**9,6**	**4,1**
leaves	SD	7,5	6,1	266	6,1	2,6	2,0	1,7
	Min	12,1	38,1	1088	0	10,3	5,1	1,3
	Max	35,4	55,0	1915	17,7	18,0	12,4	7,7
Faidherbia	n	10	10	10	4	10	10	10
albida	**MW**	**41,1**	**59,7**	**2051**	**20,4**	**12,2**	**4,4**	**1,4**
fruits	SD	8,5	9,4	388	11,3	5,5	0,6	0,6
	Min	29,3	48,7	1610	7,7	5,6	3,7	0,7
	Max	61,2	83,7	3050	35	26,8	5,7	2,5

sample		Gb	dOS	ME	PAB	XP	XA	XL
Pericopsis	n	14	14	12	4	14	14	12
laxiflora	**MW**	**8,2**	**31,9**	**1018**	**2,7**	**16,0**	**3,8**	**2,1**
leaves	SD	3,7	4,4	177	1,0	3,1	0,9	0,6
	Min	3,8	27,4	825	2,0	12,1	2,9	0,9
	Max	16,9	42,2	1452	4,1	22,3	5,3	3,2
Pterocarpus	n	18	17	16	6	17	17	16
erinaceus	**MW**	**22,6**	**46,2**	**1541**	**21,1**	**15,8**	**6,8**	**3,0**
leaves	SD	7,7	8,2	305	16,4	2,5	1,3	1,0
	Min	5,6	28,7	898	2,0	10,8	3,8	0,9
	Max	34,2	57,9	1991	45,4	20,0	8,8	5,0
Gliricidia	n	11	9	9	1	9	9	9
sepium	**MW**	**33,6**	**60,0**	**2054**	**49,8**	**20,8**	**9,1**	**4,0**
leaves	SD	4,4	4,8	223		4,8	1,1	0,7
	Min	24,8	52,2	1691		13,4	8,0	3,0
	Max	38,9	64,7	2259		26,0	10,9	5,2
Ficus	n	15	14	13	0	14	14	13
sur Forsk	**MW**	**17,5**	**45,0**	**1307**		**11,2**	**14,5**	**3,5**
leaves	SD	6,7	6,2	215		2,2	4,1	2,5
	Min	7,3	33,0	1003		7,4	6,6	2,1
	Max	32,4	55,7	1739		16,5	22,3	11,4
Ficus	n	26	23	21	13	23	23	21
sycomorus	**MW**	**24,1**	**53,8**	**1382**	**6,1**	**10,6**	**19,2**	**2,4**
leaves	SD	6,8	5,5	263	3,5	2,7	4,3	0,6
	Min	10,2	43,6	868	1,8	5,4	8,0	1,7
	Max	37,4	62,7	1773	13,1	17,1	28,1	4,1
Salvadora	n	27	27	27	2	27	27	27
persica	**MW**	**39,7**	**79,1**	**1860**	**46,3**	**14,3**	**34,6**	**1,8**
leaves	SD	4,0	3,1	176		2,2	4,6	0,5
	Min	30,9	69,9	1524	44,9	10,3	22,0	0,7
	Max	48,1	83,8	2231	47,6	19,0	45,1	2,9
Ziziphus	n	23	23	21	3	23	23	21
mauritania	**MW**	**22,4**	**48,6**	**1541**	**7,7**	**13,6**	**11,7**	**4,3**
leaves	SD	4,3	4,6	202	1,9	3,3	5,0	1,6
	Min	13,3	41,7	999	6,3	8,1	7,6	2,3
	Max	28,2	57,6	1841	9,8	20,6	28,9	7,6

sample		Gb	dOS	ME	PAB	XP	XA	XL
Calotropis	n	12	9	7	4	9	9	7
procera	**MW**	**38,3**	**69,1**	**2342**	**59,0**	**16,6**	**17,9**	**8,0**
leaves	SD	4,4	3,3	202	23,2	3,5	4,7	2,6
	Min	31,6	63,3	2049	38,0	12,1	12,4	4,8
	Max	44,7	73,6	2636	87,7	24,5	27,6	12,5
Morinda	n	10	10	10	5	10	10	10
lucida	**MW**	**32,4**	**57,8**	**2118**	**13,3**	**17,8**	**9,4**	**7,2**
leaves	SD	5,6	4,3	206	8,9	1,8	1,3	1,0
	Min	24,2	51,6	1796	3,7	15,2	7,3	5,4
	Max	39,4	63,0	2433	25,0	20,4	11,6	8,5
Hyphaene	n	17	17	17	4	17	17	17
thebaica	**MW**	**10,5**	**33,9**	**892**	**6,8**	**6,8**	**10,2**	**1,6**
leaves	SD	2,5	2,6	88	4,9	0,9	2,2	0,2
	Min	5,1	27,0	749	3,6	4,9	6,5	1,2
	Max	15,9	39,3	1060	14,1	8,9	14,5	2,0

The separation into single species and plant organs reveals in many cases a much clearer situation so that typical characteristics of nutrient properties become evident. In some species still a large variation of nutrient quality remains, however.

Only in few species dOS reaches 70 % or more, for example in Salvadora persica, a level, that has to be claimed for roughages of temperate zones. In the main bulk of samples dOS ranks between 45 and 60 %. This level also is frequently found in tropical grasses and for browse it is also confirmed by other findings (DIAGAYETE 1981). In a considerable part of the sample pool dOS is less than 45 % and ME content is below 1500 Kcal/kg T, which generally restricts or even questions the use of these species as feedstuff.

Using XP and dOS as two essential properties for determination of nutrient quality, a classification was established according to these two parameters in table 3. "+" means "above mean value of total samples", "-" means "below". Species of which parameters do not deviate much from the mean are called "indifferent".

Table 3: Classification of browse samples according to organic matter digestibility and crude protein content

dOS + XP +	dOS + XP -
Maerua crassifolia	Salvadora persica
Calotropis procera	Gleditschia triacanthos, *fruits*
Acacia tortilis, *fruits*	Faidherbia albida, *fruits*
Gliricidia sepium	Ficus sycomorus
Balanites aegyptiaca	
Acacia senegal	
Morinda lucida	
Margaritaria discoidea	
Leucaena leucocephala	
Boscia senegalensis	
Acacia seyal, *leaves*	
Afzelia africana	
dOS - XP +	**dOS - XP -**
Pericopsis laxiflora	Parinari curatellifolia
Bauhinia rufescens, *leaves*	Parkia biglobosa
Capparis decidua	Hyphaene thebaica
Pterocarpus erinaceus	Combretum nigricans
	Combretum glutinosum
	Bridelia ferruginea
	Guiera senegalensis
	Bauhinia rufescens, *fruits*
	Hymenocardia acida
	Piliostigma reticulatum
	Piliostigma thonningii
	Daniellia oliveri
	Ficus sur Forsk

Indifferent:	Ziziphus mauritania
	Faidherbia albida, *leaves*
	Acacia tortilis, *leaves*
	Grewia bicolor
	Acacia nilotica, *leaves*

From this presentation it becomes evident that based on the frequency of occurrence in the different classes, a relation between dOS and XP exists. This relation is not congent, however. There are species with low XP and high dOS, as for example Salvadora persica, or reversely, low dOS is coupled with high XP content. In the latter group, as also in species with both low XP and dOS, frequently high contents of ADL (Pericopsis laxiflora) or high tannin levels or low pronase solubility and high levels of ADF-bound N can be observed. Characteristic differences can also be found in protein availability (PAB) according to this grouping (table 4).

Table 4: Protein degradability of samples (PAB) according to grouping in table 3

group dOS	group XP	protein degradability in vitro (%)
+	+	27,2 ± 17,3
+	-	22,1 ± 17,2
-	+	12,9 ± 12,5
-	-	6,7 ± 5,4
indifferent		12,6 ± 10,5

(mean of all samples (n = 221): 16,6 ± 16,8 %)

Although the variation in all classes is very high, a clear trend exists showing that PAB is highest in the group where high dOS is coupled with high XP content and vice versa.

3.3. Relation between in vitro parameters and chemically or enzymatically derived characteristics

In the following tables first linear correlations between gas production, dOS and PAB with other results are shown in order to calculate regression equations for the prediction of in vitro digestibility parameters from more simple chemical criteria in cases where high correlations occur. The use of in vitro techniques means already a simplification as compared with in vivo methods, but it requires at least a basic instrumentation of laboratories, so that these methods are not applicable everywhere.

Table 5: Linear correlations between gas production, dOS and PAB with other parameters

		Gb	dOS	PAB
	n	1051	1051	221
XA	r	0,15	0,49	0,19
	n	1055	1051	221
XP	r	0,21	0,40	0,24
	n	922	922	
XL	r	-0,08	-0,11	n.s
	n	863	863	
XF	r	-0,37	-0,51	n.s.
	n	907		
XX	r	0,19	n.s.	n.s.
	n	867	867	221
NDF	r	-0,47	-0,58	-0,19
	n	880	880	221
ADF	r	-0,52	-0,63	-0,20
	n	875	875	221
ADL	r	-0,55	-0,60	-0,24
	n	875	875	
Cell	r	-0,28	-0,41	n.s.
	n	649	649	181
SMS	r	0,74	0,82	0,58
	n	648	648	181
SMO	r	0,74	0,81	0,56
	n	789	786	213
NPro	r	0,38	0,38	0,44
	n	831	831	220
NADF	r	-0,46	-0,51	-0,39
	n	325	323	194
TanP	r	-0,34	-0,40	-0,45
	n		1051	217
Gb	r	-	0,92	0,64
	n			217
dOS	r	-	-	0,66

It is evident that a serie of highly significant relations exist between Gb and some other fractions, for example between fiber fractions. Amongst these, the closest correlation is between Gb and ADL content. Furthermore, significant correlations were found with Gb and the parameters of N-availability (NPro, NADF, TanP and PAB), but the correlations are lower. The relatively close relation of Gb to Cellulase solubility (SMS and SMO) could be expected, as both procedures are acknowledged and suitable methods for the prediction of digestibility. The use of this close correlation is questionable, however, as the cellulase method is not unconditional a simplification compared with the gas production method with the exception that it does not require fistulated animals for its application.

The correlations between in vitro dOS and the chemically or enzymatically determined parameters are basically very similar as with Gb which is not surprising, as for the calculation of dOS Gb contributes to an essential part. In most cases the correlation with dOS are higher as with Gb alone, but they do not reach a level that would justifie to derive separate prediction equations, however. The same is with ME, therefore these relations were not shown here.

Between PAB and some of the other parameters significant correlations could also be found, but due to the large heterogenity of the total sample pool they are not satisfactory at all. Again the closest relation was found to cellulase solubility. Generally significant correlations also exist between PAB and the different N-fractions.

Despite of the above mentioned objectives and because of the high correlations between in vitro paramenters and cellulase solubility, linear regression equations were calculated (table 6).

Table 6: Linear regression equations between Gb, dOS and PAB and cellulase solubility (SMS and SMO)

x =	equation	n	r^2	RSD (%)	sign.
	gas production				
SMS	y = 0,477 x + 3,30	649	0,551	14,8	***
SMO	y = 0,458 x - 0,76	648	0,550	14,8	***
	dOS				
SMS	y = 0,569 x + 16,99	649	0,666	13,8	***
SMO	y = 0,543 x + 20,19	648	0,656	14,1	***
	PAB				
SMS	y = 0,535 x + 13,63	181	0,336	75,5	***
SMO	y = 0,490 x + 9,51	181	0,310	77,1	***

Although the best relations were selected here, residual standard deviations of about 15 % remain which is still not quite satisfactory.

The main statement from these findings is, that from the total sample pool it was not possible to derive satisfying relationships or even prediction equations due to the enormous heterogenity of composition of the samples. Therefore a simplified estimation of digestibility using chemical parameters seems to be not possible by this way. It was proved that the establishment of multiple regression equations did not improve the precision of estimate to a reasonable extent and therefore it is not shown here.

3.4. Estimation of in vitro digestibility by near-infrared-reflectance spectroscopy

In this project the prevailing part of the samples were also analyzed by near-infrared-reflectance spectroscopy (NIRS) (SINNAEVE 1994). For detailed description and results see the report of this group (chapter VIII). Here only a short summary of the results concerning the estimation of in vitro digestibility is given (table 7).

Table 7: Estimation of in vitro digestibility using NIRS (SINNAEVE et al. 1994)

parameter	n	MW	SD	calibration		validation	
				SE	R^2	SE	R^2
gas prod.	906	23,4	11,4	4,54	0,82	4,77	0,80
dOS	835	48,5	12,4	3,97	0,89	4,22	0,88
ME	721	1586	433	163	0,84	173	0,82
PAB	94	10,2	15,0	5,25	0,79	6,43	0,68

It is evident that a fairly precise prediction of the in vitro parameters is possible with NIRS, especially for the estimation of dOS. So this method seems to be the only alternative to derive useful prediction equations for the energetic feed value from the total sample pool. Therefore, from these results it can be recommended, that the NIRS method as an indirect and rapid technique should be used to a larger extent in the future also for this type of samples as robust and precise prediction equations have been established and are in hand for its use.

3.5. Results of different product groups

3.5.1. Relation between in vitro digestibility and chemical or enzymatical parameters.

To obtain more precise and specific results, the formation of different product groups from the total sample pool seems to be necessary. By this it becomes possible to reveal specific coherences. This statement was already given in the article of ARBELOT (1993) from which some results are taken and shown in the following chapter. The author has first selected the product group of "leaves" out of the total pool and thereafter selected more specific groups to obtain and interpret specific relations. (table 8)

Table 8: Correlation between dOS and PAB respectively with other parameters in total leaves and leaves of legumes and non-legumes (ARBELOT 1993).

	dOS			PAB		
	leaves	Legum.	≠Legum.	leaves	Legum.	≠Legum.
n	80	39	41	80	39	41
NDF	-0,60	-0,56	-0,63	-0,39	-0,35	-0,49
ADF	-0,64	-0,68	-0,63	-0,33	-0,39	-0,34
ADL	-0,61	-0,74	-0,57	-0,35	-0,46	ns
XP	0,47	0,60	0,48	0,63	0,60	0,72
NADF	-0,40	-0,55	-0,30	-0,27	-0,36	ns
ADFIN	0,51	0,69	0,48	0,69	0,66	0,78
SMS	0,83	0,79	0,84	0,60	0,60	0,63
NPro	0,50	0,56	0,47	0,75	0,72	0,79
TanP	-0,49	-0,37	-0,56	-0,47	-0,42	-0,55
PAB	0,67	0,67	0,68			

Irrespective of the much smaller sample size tested here, it becomes evident, that the correlations are partly much higher than observed in the total sample pool (table 5). Again the closest relation is found between dOS and cellulase solubility (SMS), but also to the different fiber fractions high correltations could be found now, especially in the group of legumes. In many cases much higher correlations can be obtained also between PAB and other N-fractions, especially to ADF- and pronase-soluble N in the group of non-legumes.

Dividing the sample pool into single species, ARBELOT could demonstrate, that the relations between these parameters are getting even more tight (table 9).

Table 9: Correlations between dOS and chemically/enzymatically determined parameters in leaves of single species (ARBELOT 1993)

species	NDF	ADF	ADL	XF	XP	ADFIN	SMO
Ficus sycomorus (n = 14)					0,72	0,71	0,54
Guiera senegalensis (n = 7)	-0,90	-0,84	-0,78	-0,93	0,85	0,80	0,90
Daniellia oliveri (n = 15)					0,98	0,97	0,89
Pterocarpus erinaceus (n = 14)		-0,87	-0,82		0,62	0,88	0,95
Morinda lucida (n = 7)		-0,91	-0,78				0,86

It becomes evident that specific relations exist in these single species. In *Ficus sycomorus* and *Daniellia oliveri* a close correlation can be found between dOS and XP and ADF-soluble N respectively, whereas in *Guiera senegalensis*, *Pterocarpus erinaceus* and *Morinda lucida* th closest relations exist to the fiber fractions. Generally, as expected, the correlations to the cellulase solubility are high.

In addition, these results also show, that specific product groups have to be formed when the aim is to estimate dOS from simple chemical parameters. This seems to be possible for the present sample pool under investigation, as from the most important plant families and species a sufficient number of observations are in hand.

Guided by this sample material, ARBELOT (1993) has tried to calculate specific multiple regression equations for the prediction of dOS from chemical and enzymatical parameters (table 10).

First of all, a hierarchical division of leaf material according to "favourable" and "non-favourable" composition (group 1 and 2) was done, after that, the four sample groups according to their NIR-spectra (see chapter 3.5.2.) were evaluated, finally single plant families and species were regarded.

Table 10: Regression equations for the prediction of dOS of leaves (except NIR-groups) from chemically and enzymatically determined parameters (ARBELOT 1993)

group (n)	dOS	s	equation	r^2	$s_{y.x}$
all leaves (335)	48,3	12,4	0,63SMO + 0,28NDF + 0,32 XP	0,74	6,39
legumes (77)	40,9	8,5	0,71SMO + 0,15NDF	0,81	3,79
non-legumes (117)	51,2	13,7	0,85SMO + 0,47Cel	0,89	4,58
gr. 1 (favourable)(113)	56,6	11,0	0,47SMO + 0,42NPro + 0,65XL + 23,7	0,50	7,89
gr. 2 (unfavour.)(138)	40,4	8,2	0,87SMO + 0,76NDF - 0,42XF - 24,8	0,72	4,39
group 1 NIR (88)	44,3	8,3	0,29SMO - 0,32XF + 0,57Cel + 0,59INADF + 20,26	0,71	4,62
group 2 NIR (18)	52,8	5,6	0,31SMO + 0,85NPro + 26,01	0,91	1,76
group 3 NIR (47)	57,4	6,0	0,29SMO + 0,92NPro + 0,54INADF + 39,82	0,57	4,09
group 4 NIR (13)	75,3	8,1	- 0,83ADL + 82,89	0,71	3,51
Mimosaceae (44)	47,1	9,9	0,40SMO + 24,59	0,66	6,68
Anacardiaceae (16)	45,9	4,4	0,23SMO - 0,45Cel + 43,18	0,62	2,78
Moraceae (28)	52,2	8,3	0,45SMO + 0,75Cel	0,77	3,69
Caesalpiniaceae (35)	43,0	6,6	0,59SMO + 0,49NDF - 0,34XF + 0,43INADF	0,87	2,80
Fabaceae (25)	48,1	13,0	1,11SMO + 0,38Cel - 1,39NPro	0,91	3,09
Ficus sur Forsk (12)	45,4	5,8	0,96SMO	0,55	4,08
Boscia senegalens.(16)	53,6	2,5	0,45SMO - 0,92NPro + 38,91	0,56	1,74
Spondias mombin (9)	48,2	3,9	- 0,67ADF + 70,51	0,73	2,19
Ziziphus mauritan.(9)	50,3	5,7	0,51SMO + 1,59Hemic + 39,09	0,77	3,18
Piliostigma thonn.(8)	42,4	4,8	- 0,77XF + 64,62	0,79	2,39
Parkia biglobosa (6)	31,5	2,0	0,66Hemic + 25,03	0,80	1,01
Ficus sycomorus (14)	52,4	5,4	0,37SMO + 0,42Cel + 1,16XP	0,85	2,39
Guiera senegalens.(9)	35,8	5,9	- 1,08XF + 65,26	0,79	2,65
Acacia nilotica (11)	50,9	8,0	2,82INADF	0,65	4,37
Pterocarpus erinac.(14)	44,9	8,3	0,93SMO	0,91	2,61
Daniellia oliveri (18)	41,8	7,7	1,72XP + 19,91	0,93	1,86
Morinda lucida (10)	57,7	4,1	- 0,79ADF - 2,03NPro + 94,33	0,93	1,29

First of all, the division according to legumes and non-legumes gives an improved accuracy of prediction, but not the grouping according to "favourable" and "non-favourable" nutrient composition. The division according to NIR-spectra or plant families respectively, is also not always satisfactory. On the level of single species, the number of observations and also the scattering of values is reduced, however, the latter resulting in lower R^2. Nevertheless, the residual standard errors of the equations are frequently relatively low.

Unfortunately in most of the equations, cellulase solubility is found as predictor. This may be a problem, as already mentioned, the determination of cellulase solubility is causing at least the same analytical efforts as compared with the direct measurement of in vitro digestibility using the gas production method. Therefore, these equations are more of theoretical interest. Of much more importance seems to be the fact, that only on the level of single species prediction equations can be obtained using the more simple chemical parameters as for instance the different fiber fractions, which means a real simplification. In this cases it is to point out, however, that these equations are strictly specific for the respective species and cannot be used for the prediction of digestibility of other species. This can also be demonstrated by the fact, that neither the variables chosen, nor their regression coefficients show any consistency.

In addition, corresponding equations were derived by ARBELOT (1993) for the prediction of PAB, which are given in table 11. The partition of the total leaf material was done according to legumes and non-legumes, botanical families and some single species. It is to notice, that for PAB the dimension "% available N in dry matter" is used here.

Table 11: Regression equations for the prediction of PAB of leaves from chemically and enzymatically determined parameters (ARBELOT 1993)

group (n)	PAB	s	equation	r^2	$s_{y.x}$
all leaves (84)	2,4	3,3	0,04SMS + 0,02INADF + 0,24TanP - 1,99	0,51	1,8
legumes (41)	2,4	3,1	0,35INADF + 0,43XL + 0,16Cel - 7,14	0,53	1,9
non-legumes (43)	2,5	3,4	0,38INADF - 0,08XX - 0,16Hemic	0,70	1,4
Mimosaceae (18)	2,7	3,0	0,74NPro + 0,45XL	0,58	2,1
Caesalpiniaceae (12)	1,1	1,4	0,28INADF + 0,09NDF - 6,21	0,81	0,7
Combretaceae (16)	0,3	0,3	- 0,05NDF + 0,06Cel + 1,28	0,55	0,4
Moraceae (13)	2,1	2,1	0,46INADF - 2,96	0,77	1,0
Fabaceae (11)	3,1	4,1	0,30SMS + 1,50NPro - 17,34	0,92	0,8
Ficus sycomorus (10)	0,6	0,4	0,11XP + 0,05ADL - 1,01	0,75	0,1
Pterocarpus erinac.(6)	3,4	3,0	0,39SMS - 16,0	0,84	1,3
Daniellia oliveri (7)	0,8	0,8	0,38INADF - 1,75	0,86	0,4

As expected, significant regression equations exist between PAB and the different fractions characterizing nitrogen, as XP, ADF- and pronase-soluble N, but also in some cases between tannin content. It is to point out, however, that in all of these equations the residual standard error remains very high.

3.5.2. NIRS

By formation of product groups according to the similarity of NIR-spectra, SINNAEVE et al. (1994) could also obtain a much better accuracy of prediction using the NIR method. The authors formed the following groups according to guiding species:

group 1	*Acacia senegal, Balanites aegyptiaca*
group 2	*Boscia senegalensis*
group 3	*Ficus sycomorus, Daniellia oliveri, Ziziphus mauritania*
group 4	*Salvadora persica*

Table 12: Accuracy of prediction of in vitro results in different botanical groups formed according to their similarity of spectra (SINNAEVE et al. 1994)

parameter	n	MW	SD	calibration		validation	
				SE	R^2	SE	R^2
group 1							
gas production	96	18,7	6,1	1,47	0,94	1,63	0,93
dOS	87	30,2	6,9	3,28	0,74	4,03	0,60
ME	87	1899	272	153	0,68	176	0,60
group 2							
gas production	36	24,1	3,9	1,26	0,86	1,64	0,77
dOS	35	51,8	5,4	1,53	0,90	2,13	0,82
ME	33	1592	193	72	0,83	96	0,71
group 3							
gas production	181	20,5	8,9	3,3	0,86	3,86	0,81
dOS	167	46,3	9,4	2,91	0,91	3,35	0,88
ME	153	1419	328	134	0,83	161	0,76
group 4							
gas production	35	34,3	9,1	2,5	0,93	3,3	0,87
dOS	35	67,5	14,9	1,81	0,99	2,55	0,97
ME	28	1854	283	145	0,65	173	0,5

In most cases, the highest accuracy can be obtained in estimating dOS, probably as here besides gas production crude protein is necessary for its calculation and as XP can be predicted with NIR always with high accuracy. The reason for the generally lower accuracy of prediction of ME remains unclear, as here, except the crude lipid contents, the same analytical parameters are used for calculation (gas production, XP, XA).

3.5.3. Characterization of nutritive value of *Faidherbia albida (Acacia albida)*

Due to its wide distribution and utilization as feedstuff, *Faidherbia albida* gains special attention. Therefore, from the present data, a separate evaluation of its nutritive properties was established. First, the most relevant data describing nutritive value for all plant organs and separately for leaves and fruits are given in table 13.

It is evident, that a separate representation according to plant organs is useful, as leaves and fruits are not only different in its in vitro results, but also show characteristic differences in its crude nutrient composition. Although leaves contain more crude protein and lipids, gas production and hence digestibility and ME content is lower. This is primarily due to the higher degree of lignification. Also the crude protein fraction has different properties. The in vitro protein availability in leaves is lower, which is in accordance to lower pronase-solubility and higher contents of ADF-bound N. One reason for this could also be the higher tannin content of leaves (2,4 vs. 0,6 %). The use of crude fiber as a measure for feed evaluation is useless, as its content in leaves is less than in fruits and therefore stands in reverse relation to in vitro digestibility and to cellulase solubility.

From the data given in table 13, several regression equations to predict in vitro parameters were calculated and given in table 14. As no statistically significant equations could be derived for the group of leaves, they are not shown in the table.

Table 13: Nutrient composition and nutritive value of *Faidherbia albida* (all samples analyzed for in vitro digestibility)

sample		Gb	dOS	ME	PAB	XA	XP	XL	XF	NDF	ADF	ADL	SMS	NPro	NADF
Faidherbia	n	22	22	22	11	22	22	22	22	22	22	22	20	21	22
albida	**MW**	**31,1**	**53,2**	**1790**	**11,8**	**7,2**	**13,4**	**2,9**	**25,0**	**42,8**	**32,6**	**12,3**	**58,7**	**41,6**	**18,7**
total	SD	12,2	9,7	401	10,3	3,1	4,2	1,9	7,4	9,0	9,4	6,6	13,9	22,0	11,1
	Min	12,1	38,1	1088	0	3,7	5,6	0,7	8,1	21,1	15,7	4,2	32,0	13,7	5,2
	Max	61,2	83,7	3050	35,0	12,4	26,8	7,7	44,5	66,0	57,4	34,2	92,9	77,0	47,4
Faidherbia	n	12	12	12	7	12	12	12	12	12	12	12	10	11	12
albida	**MW**	**22,7**	**47,8**	**1573**	**7,0**	**9,6**	**14,4**	**4,1**	**23,9**	**44,5**	**33,8**	**15,6**	**48,7**	**24,5**	**24,8**
leaves	SD	7,5	6,1	266	6,1	2,0	2,6	1,7	7,9	10,1	11,6	7,3	9,9	12,6	11,5
	Min	12,1	38,1	1088	0	5,1	10,3	1,3	15,5	31,0	19,7	7,9	32,0	13,7	9,7
	Max	35,4	55,0	1915	17,7	12,4	18,0	7,7	44,5	66,0	57,4	34,2	57,0	60,3	47,4
Faidherbia	n	10	10	10	4	10	10	10	10	10	10	10	10	10	10
albida	**MW**	**41,1**	**59,7**	**2051**	**20,4**	**4,4**	**12,2**	**1,4**	**26,3**	**40,6**	**31,1**	**8,3**	**68,7**	**60,5**	**11,2**
fruits	SD	8,5	9,4	388	11,3	0,6	5,5	0,6	6,7	7,5	6,0	1,9	9,2	12,1	4,0
	Min	29,3	48,7	1610	7,7	3,7	5,6	0,7	8,1	21,1	15,7	4,2	61,9	40,6	5,2
	Max	61,2	83,7	3050	35,0	5,7	26,8	2,5	32,1	47,9	35,9	10,4	92,9	77,0	18,5

Table 14: Linear regression equations between dOS (y) and other parameters in Faidherbia albida (fruits)

x =	equation	n	r^2	RSD (%)	sign.
XP	y = 1,45 x + 42,0	10	0,72	8,9	**
XF	y = - 1,30 x + 93,76	10	0,86	6,2	***
NDF	y = - 1,17 x + 107,36	10	0,87	6,0	***
ADF	y = - 1,46 x + 105,2	10	0,88	5,9	***
ADL	y = - 3,81 x + 91,17	10	0,56	11,1	*
Cell.	y = - 2,02 x + 105,8	10	0,91	5,1	***
ADF +NADF	y = - 1,85x_1+ 0,77x_2+108,6	10	0,92	5,1	***

In the group of fruits significant relations between in vitro digestibility and chemical composition are existing. Especially from the different fiber fractions a fairly precise estimation of diegestibility is possible. For practical purpose, the equation using ADF as predictor can be recommended. This equation is indeed a real simplification, as ADF can be determined easily and with a high reprodicibility.

Unfortunately, no corresponding equations with statistical significance could be derived from the group of leaves, so that there seems to be no possibility for the estimation of digestibility from these nutrients.

Equations derived from the total sample pool (leaves and fruits together) had also not the precision required. As the properties of fruits and leaves are so much different, it is not possible to use a common equation for both product groups.

4. Conclusions

Organic matter digestibility or content of metabolizable energy, respectively, are essential figures for nutritive value of feedstuffs. In addition, besides the knowledge of protein content, characterization of its availability or ruminal degradability is important.

Therefore, in the present investigations studies on in vitro methods using rumen liquor were carried out. The gas production method, which was developped in Hohenheim was used for the present study, as this technique is rather effective but simple so allowing the analysis of most of the samples collected during the course of the present programme.

The gas production method was calibrated using 400 samples of known in vivo digestibility and validated with another 300 samples tested in vivo (MENKE and STEINGASS 1988). The samples used for this purpose mainly consisted of different roughages from temperate zones. Only few comparisons with in vivo results of feeds of tropical origin were possible so far, but showed a general fit within the normal range of error. As the samples used for calibration of the method had a similar range in digestibility of organic matter (29,7 - 94,8 %) as the samples analyzed in the present study

(16,0 - 87,3 %), a general usefulness of the prediction equations can be imputed. A further reference to this is the fact, that a relatively close relation exists between the digestibility calculated from gas production method and from cellulase solubility (SMS; SMO), which is a completely independent procedure but is reputed to be also a reliable method for estimation of digestibility. The very close correlation in certain groups of feeds would not exist if one one these methods would be basically inadequate as an estimate of digestibility.

Nevertheless, it seems to be urgently necessary to carry out comparisons with both methods using a greater number of tropical browse feeds with known in vivo digestibility to be able, if necessary, to adapt and precise prediction equations to those feedstuffs.

A further question within the present study was, to predict the results of the gas production method, which is the method next to the animal trial, using more simple chemically or physically derived parameters. The main result was, that for the whole sample pool, all the chemical methods applied failed to predict in vitro digestibility with satisfactory accuracy. Neither crude nutrient nor the different fiber or protein fractions were suitable for this purpose. The reason is the extraordinary wide heterogenity of the sample pool which contains a wide variety of different plant species and -organs, grown at different seasons, conditions and sites. In addition, the presence of refractory or inhibitory substances, as for example tannins or lignin seems to be of significance.

The estimation of digestibility from chemical criteria only lead to satisfactory results, when specific product groups were formed, but even so not in every case. This could be demonstrated in *Faidherbia albida*, where it was possible to derive suitable prediction equations for fruits, but not for leaves. It has to be pointed out, however, that those specific equations are less robust due to the relatively small numbers of observations they are based upon.

Another great disadvantage of the formation of product groups is the fact, that they are strictly specific which does not allow their application to other samples. In the present study, however, from most of the important species a sufficient number of observations could be collected allowing the formation of data sheets with comprehensive parameters for its nutritive value.

It could be demonstrated, that the NIR-spectroscopy is a very efficient and suitable method not only for prediction of nutrient composition but also for the estimation of digestibility and energy content. Only with this technique it was possible to estimate the relevant criteria of nutritive value with good accuracy without beeing forced to form very detailed product group principally. A serie of robust prediction equations could be derived, which are precise enough to be able to estimate corresponding feeds in future investigations. Therefore, a broad use of this method can be recommended for this purpose.

In 221 samples, ruminal protein availability or degradability was estimated in vitro. The values were generally very low and seldom exceeded 50 %, whereas the normal range of common feeds is 50 - 80 %. The main disadvantage of this method is, that in contrary to the common gas production method for the estimation of digestibility, it was not calibrated using in vivo results, as it cannot be calibrated in this common way. Nevertheless, this approach gives further informations about the properties of the crude protein fraction. In addition, it was possible to derive correlations to other quality criteria of protein and to tannin contents in several product groups (see table 11). Only in samples having no tannins, low ADF-bound nitrogen and high pronase solubility the in vitro protein degradability remarkably exceeded the average values. From this it can be concluded, that this technique may be suitable as a first screening. If, for example, PAB exceeds 30 % it can be stated, that at the same time tannin contents and ADF-bound nitrogen must be very low and pronase solubility is high, respectively.

An improvement of this method would be achieved, when it succeeds to make comparisons to in vivo or in sacco results in order to obtain at least a certain standardisation. The main objective is, however, to standardize the in vivo trials as such.

In general, the present investigations could contribute together with efforts in the other subprojects to establish a comprehensive review and documentation of the nutritive value of West African browse feeds. For all of the major important plants used as feeds it is possible to make up data sheets containing most of the relevant figures describing nutritive value. Therefore, the practical user will be enabled to uncover the major constraints in feeding and calculate balanced rations more efficiently and precisely in future.

5. Summary

In the present investigations, organic matter digestibility and content of metabolizable energy was estimated in 1123 samples of African browse using the gas production method (MENKE and STEINGASS 1988). In addition, in vitro ruminal protein availability was estimated in a part of the samples (n = 221).

The average OM-digestibilty was about 50 % corresponding with an average content of metabolizable energy of 1620 Kcal/kg DM. Depending on plant species and -organs great differences of the results were obtained, revealing characteristic attributes of the single species. Protein availability was generally very low due to the presence of inhibitory substances in many feeds.

Due to the great heterogenity of the material under test, it was not possible to derive precise prediction equations for the estimation of digestibility from chemical or enzymatical parameters based on the whole sample pool. Only after formation of specific product groups (single species and/or organs), it was possible to derive prediction equations with satifactory accuracy using simple chemical characteristics.

Fairly precise prediction equations of nutritive value based on the whole sample pool was possible using NIR-spectroscopy, however. Therefore, it can be recommended to use this method for such samples in future investigations.

6. Literature

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